

ASTHENOPSIS WHITEHOUSE, 1939 (TRILOBITA, MIDDLE CAMBRIAN)
IN NORTHERN AUSTRALIA

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ABSTRACT

Comparisons of the Trilobite *Asthenopsis* with other genera, previously confused with it, show it to be a distinct taxon containing six Australian species. Apart from the type species, *Asthenopsis levior* Whitehouse, 1939, five are described as new (*queenslandica*, *rhinostrongyla*, *unquinsepta*, *butorosa*, and *opalensis*). Another new species is recognized but not named and another population is compared with *A. rhinostrongyla*. Some remarks are also made on muscle insertions.

Since Whitehouse erected the genus in 1939 and introduced *Asthenopsis levior* as type, no new species have been assigned and those European species placed there by Whitehouse may now be more correctly placed in other genera. Of the species from China referred by Walcott (1913) to *Solenopleura*, by Kobayashi (1935) to *Solenoparia*, and by Whitehouse (1939) to *Asthenopsis*, none belong to *Asthenopsis*. No references to *Asthenopsis* have appeared since 1939 other than the short note (Opik 1967, p.184) indicating its ptychoparioid affinities and several cursory identifications at the generic level.

Terms used in the systematics are those defined by Harrington, Moore, and Stubblefield (*in* Moore 1959), glabella being used to include the occipital ring. Notation for muscle areas of glabella and points on facial suture follow Richter and Richter (1940). I have referred to any sagittal or exsagittal dimension in terms of length and any transverse dimension in terms of width.

Figured material is housed in the Commonwealth Palaeontological Collection (CPC), Department of Geology, Australian National University (ANU), or Department of Geology, University of Queensland (UQF). Locality numbers referred to are in the registers of the Bureau of Mineral Resources, Canberra (M, H, or MNF), Department of Geology, Australian National University (ANU), or Department of Geology, University of Queensland (UQL).

Genus *Asthenopsis* Whitehouse, 1939

TYPE SPECIES: *Asthenopsis levior* Whitehouse, 1939 by original designation.

GENERIC DIAGNOSIS

Ptychoparioid with glabella of slightly variable length, three or four pairs of lateral glabellar furrows, an anteromedial glabellar muscle scar, slightly tapering, straight to very slightly waisted lateral glabellar margins. Furrow l_p long and forked adaxially. Fixed cheeks wide (0.7 - 0.9 of basal glabellar width). Eye ridges paired or tripled. Anterior axial furrow weakly or not impressed, always much weaker than lateral axial furrow, and shallowing through ontogeny. Fossulae deep. Brim 0.2 - 0.5 of glabellar length. Border furrow with wide pits anterior to the fossulae. Palpebral lobes short and near midlength of cephalon or slightly posterior to it. Free cheek with high eye socle, with strong anterior doublural projection, and genal spine that is commonly deflected slightly laterally to break the cephalic marginal curve at the level of the posterior of the palpebral lobe.

Thorax of 14 segments. Pleural tips either rounded, broadly squared or spinose. Pygidium relatively small (c. 0.3 of cephalic length), transverse, and moderately vaulted to flat in pleural areas. Border furrow poorly to not impressed. Doublure no wider than border, usually

very much less. Ornament highly variable from species to species including smooth, finely papillose, and tuberculate (both fine and coarse).

COMPARISON

Solenopleura Angelin, 1854 with *holometopa* as type is a distinct genus characterized by the lack of preglabellar field, glabella occupying a larger percentage of the cranial surface, fixed cheek 0.6 or less of basal glabellar width (*canaliculata* is probably not congeneric), almost aspinose cheek, and more quadrangular pygidium. *Jincella* Snajdr, 1957 with *S. prantli* Ruzicka, 1944 as type is distinguished from *Asthenopsis* by the short convex border, short preglabellar field, well impressed anterior axial furrow, rather conical glabellar shape, narrow fixed cheeks, well impressed glabellar furrows, and long narrow posterior limb. *Solenoparia* Kobayashi, 1935 with *Ptychoparia toxus* Walcott, 1905 (Walcott 1913, pl. 19, fig. 10) as type is distinguished by its short convex border, narrow fixed cheeks, longer palpebral lobes, glabella occupying larger part of cranial area, and less transverse pygidium. *Kounamkites* Lermontova in Chernysheva, 1956 based on *virgatus* Chernysheva, 1956 is distinguished by the short border relative to brim, strongly diverging anterior branches of suture, well impressed anterior axial furrow, undeflected genal spines, and less transverse pygidium.

The content and validity of the several genera mentioned above are not commented on herein as I have had no first hand experience with them. However, they are sufficiently known to be sure of their distinction from *Asthenopsis*.

Eosioptychoparia kochibei (Walcott, 1911) from Manchuria represents a very similar genus even to the deflected genal spine but distinctions are evident. I shall describe *E. kochibei* more fully in a forthcoming paper.

MUSCULATURE

As illustrated for *Triarthrus* (Cisne, 1974, fig. 2) the ventral longitudinal muscles of *Asthenopsis* are interpreted as running forward to the two wide slightly deeper areas of the anterior border furrow situated directly in front of the fossulae. These muscles that run back to the major ventral endoskeletal bars to which attach many of the muscles of the mouth parts and other appendages, are probably strongly digitate anteriorly (by homology with the cephalocarid *Hutchinsoniella*, see Hessler 1964) with many small attachment sites on the cuticle.

In passing it should be noted that a large percentage of trilobites have some structures in or near the anterior border furrow (i.e. low anteriorly on the sagittal or exsagittal glabellar profile) that can be readily interpreted as ventral longitudinal muscle attachment sites. Those lacking such structures are not precluded from having muscle insertions in this position but are simply interpreted as not showing them in any distinctive way. In the Crepicephalidae the two or three wide distinctive pits in the border furrow are formed by several smaller circular pits providing apodemes for the digitations of the ventral longitudinal muscles. This structure also suggests that broad depressions and discrete pits may be analogous. Many post-Cambrian trilobites exhibit strong apodemes or muscle scars well forward on the cephalon that would be ideally placed for attachment of the ventral longitudinal muscles.

The dorsal longitudinal muscles of *Asthenopsis* are interpreted as anchoring anteriorly to the glabellar furrows and posteriorly to the apodemes of the transaxial furrows. While these muscles form single sheaths the full length of the animal, they are also attached to each segmental apodemal area to allow intersegmental mechanisms to function.

A very small muscle scar is situated anteromedially on the glabella. I am unable to find the description of any other ptychoparioid referring to a similarly situated muscle scar. Jell (1975, p. 23) interpreted a muscle scar in this position on a species of *Pagetia* and discussed its possible function as a hypostomal diductor muscle by direct homology with the living notostracan *Triops*. In many dalmanitaceans a pit is present anteromedially on the glabella (Campbell in press) which may be homologous with that of *Pagetia* and indeed with that of *Asthenopsis*.

AFFINITIES

The taxonomic position of *Asthenopsis* is not clear. Originally placed in the Solenopleuridae it has been regarded as correctly assigned except for the statement by Opik (1967, p. 184) that it may be regarded as a ptychopariid. I agree with Opik and believe that in the light of new species described herein the genus can be confidently divorced from any close relationship with the group of genera that have come to be known as the Solenopleuridae. I shall not make any assignment at this stage as I am at present engaged in a numerical taxonomic study of ptychoparioids and do not wish to pre-empt those results.

Asthenopsis levior Whitehouse, 1939
(Fig. 1a; Plate 31, figs. 1–9; Plate 32, figs. 1–5)

Asthenopsis levior Whitehouse, 1939, p. 214,
pl. 22, figs. 17–20.

MATERIAL EXAMINED

HOLOTYPE: UQF3337, an external mould of a complete exoskeleton the counterpart of which is missing from the University of Queensland collections, from V Creek at the Undilla to Camooweal Road crossing.

OTHER MATERIAL. Four cranidia (C), 1 free cheek (FC), 2 pygidia (P), and 1 thorax (T) from M41 at the base of an isolated hill of Split Rock Sandstone 4.8 km east of Douglas Creek on the Old Burketown Road (lat. 19° 27.5'S., long. 138° 37'E); 3C, 2P, and one complete from M247 at Barkly No. 7 Bore west of Yelvertoft; 2C from the left bank of Douglas Creek halfway from the Old Burketown Road to the O'Shannassy River; 3C from 12 km south of Douglas Spring on the 'Morstone' to 'Undilla' Road; 1C and 2T from left bank of Douglas Creek at 'Morstone'; 2C from M52 1.3 km west of M41; 1FC from M139 just west of Top Hands Waterhole on the upper reaches of Harris Creek; 5C, 1P, and 3T from UQL469 on top of hill immediately east of the crossing of Harris Creek by the Camooweal to Thornton Road; 3C and 1FC from UQL3510 15 km south-west of the Thornton airstrip on the Kangaroo Flat road. This includes the figured specimens CPC17064–8 and UQF68711–4 (Pls. 31, 32). Whitehouse's originally figured specimens were also examined and are refigured herein (Pl. 31 figs. 1, 4, 6, 7).

All localities are in the V Creek Limestone except M52 which is in the Mail Change Limestone. The age of the material is the Zone of *Ptychagnostus nathorsti*.

DIAGNOSIS

Outline regularly oval. Surface ornament lacking or of minute papillae with rare slightly larger tubercles. Glabella extending 0.7 of cephalic length, with tapering straight or convex lateral margins, with truncated anterior and angular anterior corners. Three pairs of lateral glabellar furrows, smooth to very poorly impressed, with furrow 1p long and wide, furrows 2p and 3p successively shorter and narrower. Occipital node at midlength of ring. Border flat to weakly convex long and tapering laterally. Facial suture with slightly convex anterior branch in exsagittal line or slightly convergent. Eye ridges variable in prominence, paired. Palpebral lobe short, just behind midlength of glabella. Caecal ornament on extra-glabellar parts of cephalon. Thorax of 14 segments. Pleural furrows long, well impressed, running almost to pleural tips. Pleurae downturned in fulcral line, with spinose tips. Pygidium about 0.15 of total length. Axis with

three rings and terminus. Pleural areas highly vaulted with four pairs of ribs. Posterior margin concave.

DESCRIPTION

The holotype designated by Whitehouse (1939, p. 278) has a cephalon 9 mm long but other specimens have been collected with cephalon up to 16 mm long so the type is not a fully mature individual. This description is based on the more mature material and its variations from the morphology of the holotype are discussed below under DISCUSSION OF HOLOTYPE.

Exoskeleton almost twice as long as wide, moderate overall convexity with steeper slopes towards the margin. Cranidium two or three times length of pygidium. Overall shape oval but somewhat more rounded anteriorly than posteriorly.

Cranidium moderately vaulted, twice as wide as long, with moderately steep slope to border furrow in lateral profile. Glabella tapering forward to half its basal width, with straight or slightly convex sides, truncated almost transverse anterior. Anterior axial furrow very poorly impressed (represented almost entirely by a change of slope in lateral profile), never as well impressed as lateral axial furrow. Axial furrow very broadly V shaped in section, with deep fossulae anteriorly, floor raised adjacent to lobe 1p, running directly past occipital ring to margin. Occipital ring five times as wide as long, with prominent sagittal node at the midlength, posterior margin convex, tapering laterally into a low ridge that crosses the axial furrow into the posteroproximal corners of the fixed cheek. Occipital furrow poorly impressed, slightly deeper laterally, with smooth surface of apodemal pit extending up onto lobe 1p and occipital ring. Glabellar furrows three pairs in number, defined mainly as smooth areas on an otherwise weakly ornamented glabella. Furrow 1p long, directed at 30° to transverse line out of axial furrow then posteriorly at 60° to transverse line in a shorter adaxial terminally expanded section, with medial swelling just out of axial furrow. Furrow 2p shorter and narrower than 1p, of same general shape but with much narrower unexpanded adaxial part and directed less posteriorly. Anteromedian glabellar muscle scar present.

Brim downsloping much more steeply and twice as long at facial suture as axially, convex becoming more so laterally, very slightly depressed from fossulae forward to border furrow, with prominent anastomosing caeca originating out of the eye ridge and running forward into the

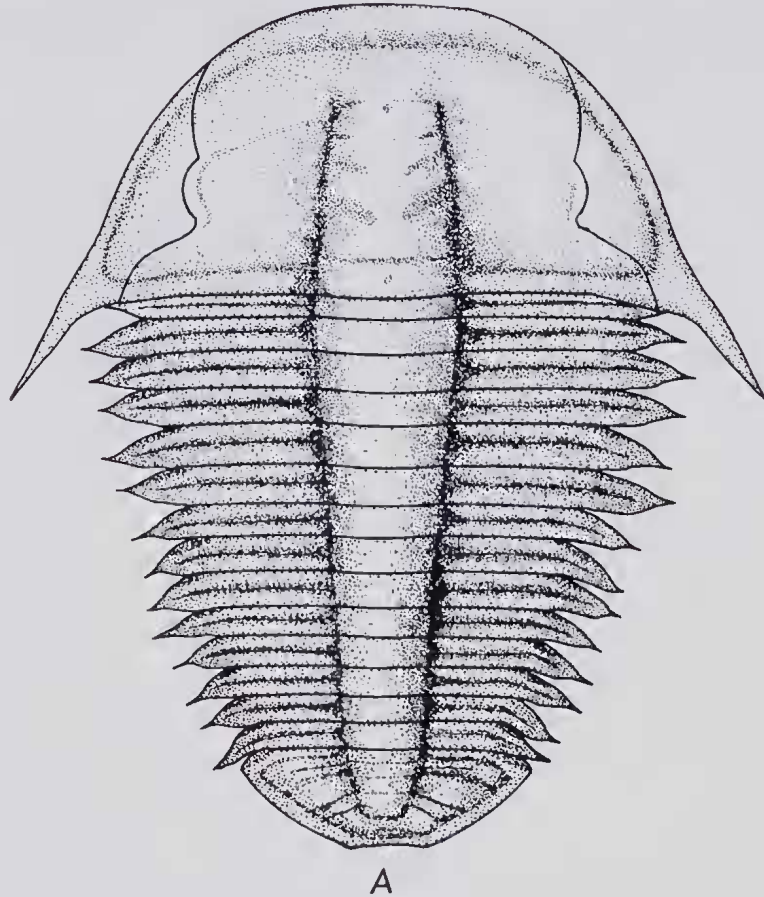
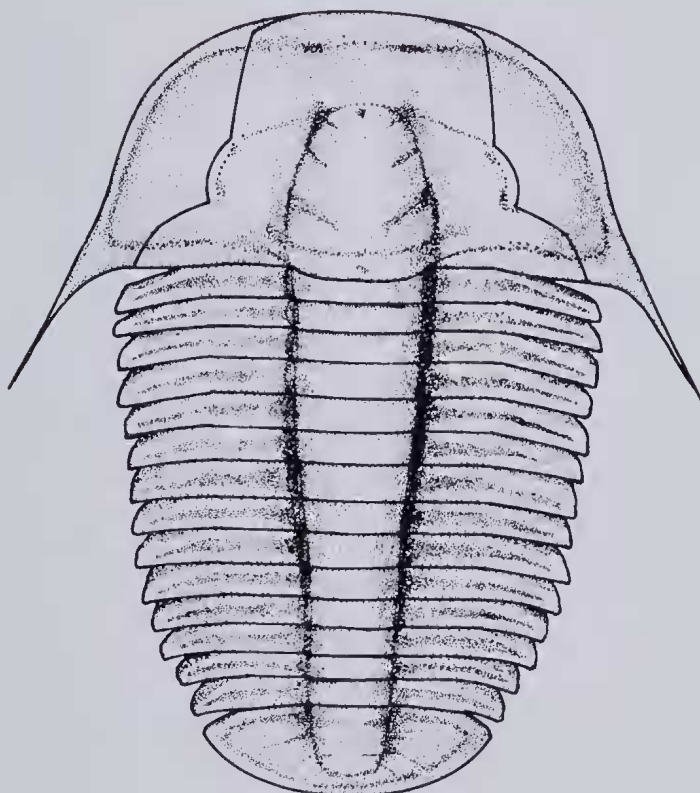


FIG. 1A: Reconstruction of *Asthenopsis levior* Whitehouse, 1939 based on holotype and UQF44314.

border. Border furrow poorly to moderately impressed, with a pair of very wide indistinct pits directly anterior to the fossulae (ventral longitudinal muscle attachment sites), transverse except for slight convexity between wide pits. Anterior border moderately convex often accentuated by sharp posterior slope but always with gently sloping anterior, highest point at midlength. Eye ridges double, prominent, continuing through the fossulae and around front of glabella as low parafrontal band, directed posteriorly at approximately 20° to transverse line. Palpebral lobe 0.25 of cephalic length, abaxially upturned, and posteriorly downturned, moderately arcuate, opposite furrow 1p and lobe 2p. Palpebral furrow moderately impressed, shallowing at midlength. Fixed cheeks 0.82 basal glabellar width, moderately convex, rising gently to palpebral lobe. Posterior limb wide and long, almost rectangular in shape except for slightly convex and posteriorly

directed anterior margin, sloping steeply abaxially, with faint caecal system posterolaterally from palpebral lobe. Posterior border furrow lengthening and deepening laterally, turned slightly forward at extremity. Posterior border lengthening and flattening laterally, with marked ridge forming high point for most of its width but meeting the posterior margin two thirds of distance from fulcrum to ω . Posterior margin straight to fulcral line (used in sense of Opik, 1967, p.57) then convex. Facial suture with $\alpha - \alpha$ only 0.6 of $\beta - \beta$, $\beta - \gamma$ variable from convex and converging to straight and exsagittal, δ at midlength of palpebral lobe, ϵ at posterior of furrow 1p. Free cheek with long anterior extension where facial suture cuts obliquely across border, β at posterior of border furrow. Margin evenly curved to base of rounded genal spine, then deflected slightly abaxially down spine. Border wide, flat to weakly convex. Eye socle low, of



B

FIG. 1B: Reconstruction of *Asthenopsis queenslandica* sp. nov. based on holotype and CPC17072.

constant height. Genal field exhibiting very low anastomosing aeaca.

Rostral plate and hypostoma unknown at present. Thorax of 14 segments each 12 times as wide as long. Articulating half ring slightly lower than axial lobe, shorter than furrow or lobe, with prominent transverse ridge near posterior forming high point and dividing smooth relatively flat anterior part from steeper granulose posterior part. Articulating furrow with posterior wall steeper and higher, with fine papillose ornament anteriorly. Axial lobe expanding slightly laterally to occupy full segmental length, flat (sag.) with transverse posterior margin. Accessory apodemal pits low abaxially, joining articulating furrow and posterior margin. Pleural furrow occupying 40–50% of fixed pleura, swinging forward and shallowing adaxially, meeting axial furrow a short distance from margin, with very shallow posterior arm adaxially giving a forked appearance,

deepening and shortening on free pleura before finishing at the midlength near the base of the pleural spine. Pleural strips of equal length except on free pleura where anterior strip shortens as it runs obliquely behind wide moderately long smooth facet. Pleural spines stout, curving slightly posteriorly. Segments not overlapping at all on fixed pleura (i.e. margins abutting) but overlapping almost all facet on free pleura. Segments transverse throughout.

Pygidium almost three times as wide as long, well vaulted, with rounded margin except for slightly concave section across axis posteriorly. Articulating half ring extending in front of otherwise transverse margin, with fine papillose ornament posteriorly. First axial ring highest part of pygidium, with posterior excavation on axial three quarters cutting out most of segmental length (sag.) with weak accessory apodemal pits in exsagittal line close to axial furrow. Second

axial ring with almost imperceptible accessory apodeme and smaller posterior excavation. First and second transaxial furrows moderately impressed with wide undeepressed apodemal areas. Posterior transaxial furrows possibly three in number, progressively weaker, and continuous. Axis parallel sided with rounded posterior, with moderately steep posterior slope to border and margin. Pleural areas with three well impressed pleural furrows and one poorly impressed interpleural furrow anteriorly, furrows deepest in fulcral line. Caecal ornament running out from axial furrow along pleural strips, through border furrow and into the border. Facets wide, relatively short, triangular, smooth and steeply sloping. Anterior pleural strip of first segment short and convex to fulcrum then longer, less convex and oblique beyond. Border furrow poorly impressed more so behind axis. Border flat and of uniform width. Ornament of fine papillae on axial rings, terminus, pleural ribs and border of some specimens, furrows smooth.

DISCUSSION OF HOLOTYPE

As already mentioned the holotype specimen represents an immature individual so it varies in several minor respects from the description given above. With the recognition of these morphogenetic changes further outlined under MORPHOGENY below comes the realization that the species has considerable intraspecific variation between individuals of the same and only slightly different size.

The holotype is crushed with only slight displacement of the free cheeks that do however, obscure the course of the facial suture. It has fine, close-spaced papillae with an occasional very widely spaced tubercle. Details of occipital ring and glabellar posterior are lost as the exoskeleton of that part has remained in the counterpart. Fossulae are deeper so the frontal area is more convex (exsag.) but less steeply sloping. The caecal network on the brim and eye ridges is less prominent. The palpebral furrow is abaxially convex and the lobe more strongly upturned. Fixed cheek width and basal glabellar width almost the same. On the thorax the ornament is coarser axially but less apparent on the pleura. On the pygidium the posterior margin is straight, the interpleural furrow is very weak, the axis does not reach so close to the margin, and the pleural areas are not so vaulted.

MORPHOGENY

The smallest individual with a complete thorax (Plate 31, fig. 2) has 14 segments and a cephalon

4 mm long so that it must be a very early holaspide. A slightly smaller cranidium (Plate 31, fig. 3) 3.5 mm long is similar to that of the complete individual. While the cephalon is shorter than 5 mm the fixed cheeks are more convex, the axial furrow is deeper, the ornament is coarser, the furrows forward from the fossulae are more evident, the palpebral lobes are relatively long extending from lobe 1p to furrow 3p or half glabellar length, pleural tips are not spinose but simply pointed.

Individuals with cranidia 5–10 mm long are characterized by the holotype described above but it should be noted that most individuals of this size range have coarser papillae than the holotype.

AFFINITIES

Asthenopsis levior is quite variable from locality to locality but only in minor details of glabellar shape, ornament, relief, and anterior course of facial suture. As no uniform variation of these characters can be observed and as the variation is not as great as between this and other species of the genus described below no other species have been separated from the relatively distinct (within the genus) *levior*.

*Asthenopsis queenslandica** sp. nov.

(Fig. 1b; Plate 33, figs. 1–8; Plate 34, fig. 1)

MATERIAL EXAMINED

HOLOTYPE: CPC17074, a complete specimen from M243 on the flood plain of Whistler Creek, 0.8 km from its junction with the Buckley River, 42 km west of Yelvertoft Homestead (Lat. 20° 04' S., long. 138° 30' E); V Creek Limestone, Zone of *Ptychagnostus nathorsti*.

OTHER MATERIAL: Three complete specimens, 14C, 2FC and 3P including CPC17070–3 and 17075–8 (Pls. 33 and 34) from M243; 2C from UQL467 4.8 km west of Redbank Creek, just west of laterite ridge between Redbank and Harris Creeks; 20C, 1FC, 8P, and several thoracic segments from UQL463 top of hill 6 km south of Thornton Homestead on left bank of West Thornton River.

Both UQL463 and 467 are in the V Creek Limestone with 463 belonging to the *Euagnostus opimus* Zone and 467 to the *Ptychagnostus punctuosus* Zone.

DIAGNOSIS

Asthenopsis with relatively square anterolateral glabellar corners, low cephalic convexity generally and in the anterior margin, four pairs of smooth

*Named for the state of Queensland.

to very poorly impressed lateral glabellar furrows, anteriorly placed occipital node, relatively long brim, doubled eye ridges, relatively narrow fixed cheeks, straight slightly converging anterior branches of facial suture, fine close spaced papillose ornament with sparse small tubereles superimposed. Pleural tips squared. Transverse pygidium having flat pleural areas, no border furrow, and an evenly curved margin.

DESCRIPTION

Cranidium four times as long as pygidium, very weakly vaulted. Glabella standing above flat to slightly abaxially rising fixed cheeks in anterior profile, subquadrate tapering only slightly forward from furrow 1p, with angular anterolateral corners and only slightly convex anterior margin. Occipital ring with small sagittal node anteriorly. Occipital furrow well impressed, short, and smooth (apodemal part) with steeper anterior than posterior wall laterally and shallow, slightly longer, with papillose ornament and steeper posterior than anterior wall axially. Glabellar furrow 4p may be present low in the axial furrow. Glabellar ornamented with fine papillae except on the apodemal areas. Brim downsloping slightly more steeply at the facial suture than axially. Eye ridges only slightly elevated, divided into two parallel ridges. Fixed cheeks 0.73 of basal glabellar width, rising gently to palpebral lobe with fine papillose ornament and a very few slightly larger tubereles interspersed, with very faint caecal network radiating from lobe 1p and from the rear of the eye. Posterior limb elongate triangular in shape, sloping steeply down abaxially. Facial suture with $\beta - \gamma$ straight and very slightly converging, δ behind midlength of palpebral lobe.

Free cheek relatively flat, not vaulted, β at posterior of border. Border convex anteriorly, flatter posteriorly, with one or two continuous parallel terrace lines near the margin, with papillose ornament. Genal spine with flat dorsal and slightly rounded ventral surfaces. Thorax of 14 segments each 15 times as wide as long. Each pleuron with fine papillae and single row of tubereles (up to 7). Free pleura with rounded anterolateral and semisquared posterolateral corners. Anterior fixed pleural margin just under posterior of next anterior segment but with margins directly opposed in same plane for short distance at fulcrum then overlapped on the free pleural facets. Segments becoming slightly anteriorly convex near the pygidium.

Pygidium with an unbroken marginal curve, and a low profile with axis standing only slightly

above flat pleural areas. Furrows all shallower than in *A. levior*, decreasing in depth posteriorly and laterally. Border furrow not impressed. Border may be defined as area beyond pleural furrows. Fine papillae on areas out of furrows and off musele sears.

MORPHOGENY

Although no small specimens with a full complement of segments are available some comments on the morphological changes with increased cranial size are pertinent. The adults described above all have cranial length of 10–12 mm whereas two other groups exist with cranial lengths of 3 mm and 5–6 mm respectively.

The 3 mm cranidia (Plate 33, figs. 2, 4) have a second order of larger tubereles scattered over the entire exoskeleton giving the same ornament as in mature individuals of *A. rhinostrongyla*. They have an anterolaterally rounded glabella, almost no glabellar furrows, better impressed anterior axial furrow, convex fixed cheeks just slightly more than half basal glabellar width and with no apparent division of the eye ridge.

The 5–6 mm cranidia (Plate 33, fig. 7) have the same ornament as the 3 mm cranidia, the anterolaterally rounded glabella, very poorly impressed glabellar furrows, virtually no anterior axial furrow, convex fixed cheeks 0.6 of basal glabellar width, and paired eye ridge.

*Asthenopsis rhinostrongyla** sp. nov.

(Fig. 2A; Plate 34, figs. 2–7;

Plate 35, figs. 1, 2)

MATERIAL EXAMINED

HOLOTYPE: CPC17080, a cranidium from H138 on the Huckitta 1:250,000 Geological map at 22°35' south latitude, 136° 02' east longitude on Arthur Creek, Northern Territory; Arthur Creek Beds, *Euagnostus opimus* Zone.

OTHER MATERIAL: Seven C, 3 FC, 1 T, and 3 P including CPC17079, 17081–6, (Pls. 34 and 35) from H138.

DIAGNOSIS

Asthenopsid with rounded anterolateral glabellar corners, flat unarched anterior border, moderate convexity, anterior branches of facial suture diverging forward and abaxially convex, relatively long palpebral lobes, ornament of very close spaced papillae over entire surface except apodemal areas, palpebral lobes and furrows, and coarse perforated tubereles interspersed sparsely

**Rhinos* (Gr.) nose, *strongylus* (Gr.) rounded, refers to the rounded glabellar anterior.

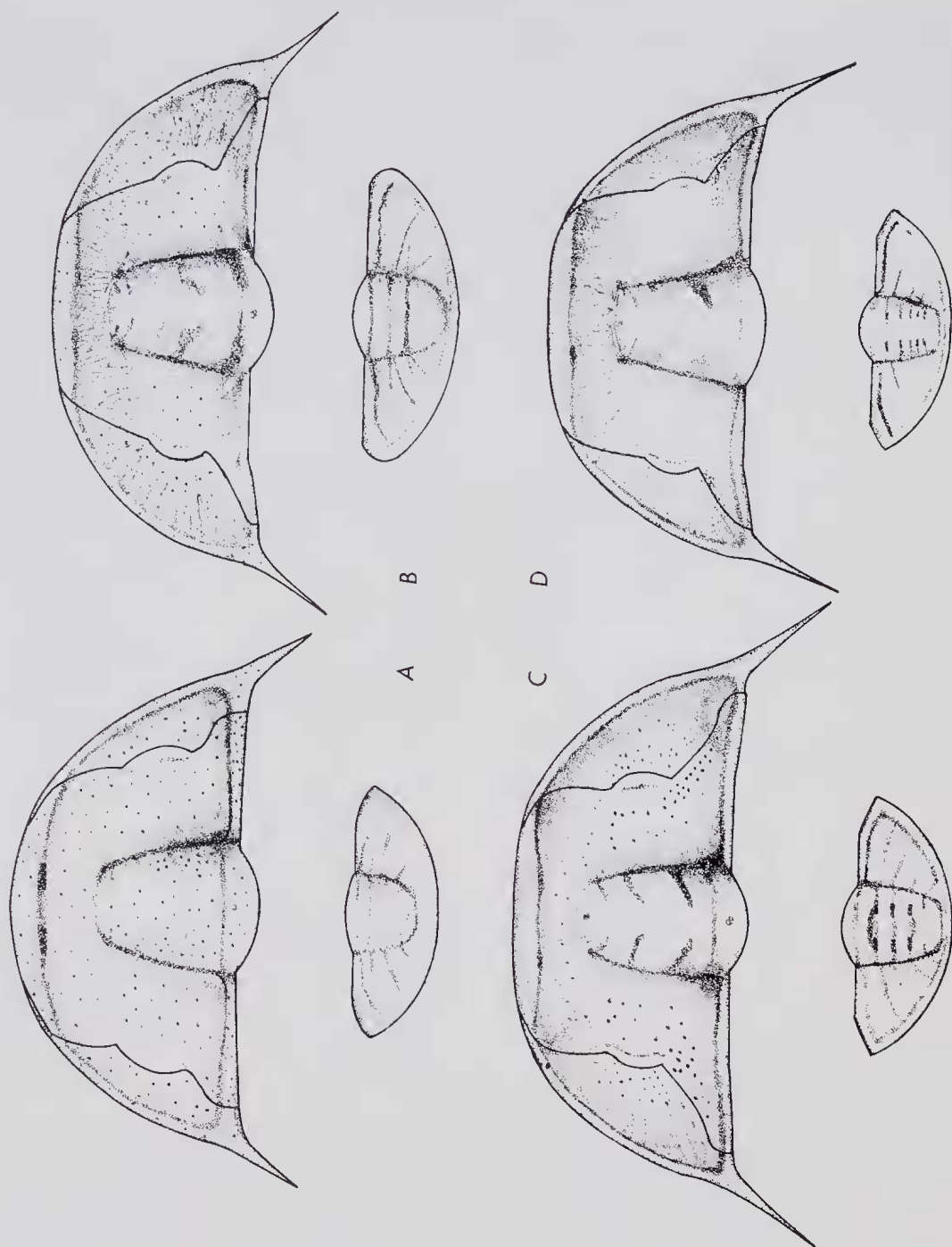


FIG. 2: Reconstruction of cephalon and pygidium of *Asthenopsis* species.

A: *Asthenopsis rhinostrongyla* sp. nov. based on the holotype, CPC17085, and CPC17086.

C: *Asthenopsis butorasa* sp. nov. based on the holotype, ANU30646, and ANU30647.

B: *Asthenopsis opalensis* sp. nov. based on the holotype, CPC17100, and CPC17102.

D: *Asthenopsis unquinsepta* sp. nov. based on the holotype, CPC17087, and CPC17088.

over the same areas. Pleural tips rounded. Transverse pygidium with flat pleural areas.

DESCRIPTION

Cranidium with moderately steep anterior slope in lateral profile. Glabella subquadrate tapering only very slightly forward to 0.8 of its basal width. Occipital furrow with markedly deeper apodemal pits, almost dumb-bell shaped apodemal areas extending onto lobe 1p and occipital ring. Four pairs of lateral glabellar furrows smooth, not depressed. Furrow 1p with adaxial part not expanded. Furrow 3p separated from axial furrow. Furrow 4p very indistinct, narrow and smooth. Occipital node situated anteriorly. Axial furrow distinctly shallower adjacent to lobe 1p and occipital ring. Eye ridge quite low and formed of two trunks. Fixed cheeks 0.8 of basal glabellar width, slightly convex and horizontal. Posterior limb steeply downslowing. Facial suture with $\delta - \beta$ convex and diverging. Posterior border furrow lengthened slightly laterally. Posterior border only moderately convex and slightly longer laterally, with its ridge not markedly distinct and not obvious beyond fulcrum. Ornament of papillae and sparse perforated tubercles over cranidium except on furrows, palpebral lobe and distal parts of posterior limb.

Free cheek doublure without ornament, extending only slightly adaxial to long anterior dorsal projection. Thorax of at least 12 segments (exact number unknown). Anterior half of half ring smooth but posterior half sloping into furrow, moderately papillose. Up to 14 large perforated tubercles on each pleural strip. Posterolateral pleural corner well rounded. Facet more than half segmental length.

Pygidium transverse with second transaxial furrow poorly impressed. Axis with relatively gentle posterior slope to flat border area. Pleural areas almost flat with one well and one poorly impressed pleural furrow separated by long flat rib bearing a poorly impressed interpleural furrow. Anterior strip of first segment lengthening markedly at and beyond fulcrum. Ornament of papillae everywhere except in furrows and close packed on high parts with large sparsely scattered tubercles over the same areas.

Asthenopsis sp. cf. *A. rhinostrongyla* sp. nov.
(Plates 38, figs. 3–7)

MATERIAL EXAMINED

Two C with FC, 1FC, and 3T including CPC17103 to 17105 and UQF68715 to 68716 from M156 (located on Camooweal 1:250,000 Geological map) on the middle

reaches of Opal Creek in the Age Creek Formation, *Ptychagnostus punctuosus* Zone, of the Currant Bush Limestone.

DESCRIPTION

Those features not consistent with *A. rhinostrongyla* are referred to comparatively in this description. Glabella with better impressed anterior axial furrow producing a distinct break in lateral profile. Axial furrow poorly impressed throughout. Palpebral lobes narrower, markedly upturned laterally. Fixed cheeks almost as wide as the base of the glabella. Facial suture with α much closer to β . Ornament, especially the papillae, more subdued, larger tubercles fewer in number. Free cheek with terrace lines prominent near margin. Border slightly narrower. Genal spine slightly more abaxially deflected. Pygidium unknown at present.

REMARKS

The nature of the glabella, anterior border and palpebral lobes along with the slightly different ornament make reference to *A. rhinostrongyla* difficult. However, when a larger population of that Northern Territory species is studied the limits of variation may be such that this material will be assignable. It should be pointed out that the cephalic convexity, anterior border arch, subtle ornament, and in one instance (Plate 38, fig. 6) short frontal area also ally this species to *A. opalensis*. However, shape of the glabella and its furrows, eye ridges, shorter palpebral lobes, and straight anterior parts of facial suture distinguish that species.

*Asthenopsis unquinsepta** sp. nov.
(Fig. 2D; Plate 35, figs. 3–8)

MATERIAL EXAMINED

HOLOTYPE: CPC17089, a cranidium from M157 on a sharp bend near the second creek junction on Opal Creek, latitude 19° 25' S, longitude 138° 35' E.; Age Creek Formation, Zone of *Ptychagnostus punctuosus*.

OTHER MATERIAL: Five C, 2 FC, and 2P including CPC17087, 17088, and 17090–2 (Pl. 35) from M157.

DIAGNOSIS

Asthenopsis with glabella tapering forward to half its basal width, glabellar anterior truncated, anterolateral glabellar corners quite angular, furrow 1p with prominent domed area at its

*From the latin numerals 1, 5, and 7, the material being from M157.

midlength abaxially, frontal area relatively long and fixed cheeks of moderate width, anterior branch of facial suture straight and converging slightly forward, eye ridges doubled, ornament on border and glabellar of fine tubercles but on frontal area and fixed cheeks of coarser close spaced tubercles. Pygidium moderately vaulted.

DESCRIPTION

Glabella tapering anteriorly to half its basal width, sharply truncate anteriorly by change in ornament, anterior axial furrow not impressed even by a change of slope. Occipital ring less than four times as wide as long with medially placed node. Occipital furrow poorly impressed on axial half, with very steep anterior wall into pronounced apodemal pits laterally. Furrow 1p with domed abaxial elevation prominent. Glabellar ornament of fine tubercles. Axial furrow very poorly impressed throughout, with diverticulum from lobe 1p conspicuous. Ventral longitudinal muscle pits poorly impressed. Frontal area with prominent caecal network standing well above surface. Eye ridges doubled. Fixed cheeks almost flat. Palpebral lobe flat, only very slightly upturned and opposite furrow and lobe 2p. $\epsilon - \omega$ directed posteriorly at moderate angle to transverse line, crossing posterior border obliquely. Posterior limb relatively long and subtriangular in shape. Posterior border furrow increasing in length beyond fulcral point. Ornament on anterior border, on glabella except furrows of fine tubercles closely spaced, absent on palpebral lobes, posterior border furrow, and border furrow; on fixed cheeks, posterior limb, and frontal area ornament of close packed coarser perforated tubercles, with occasional ones larger than the rest.

Free cheek with ornament on genal field similar to that of frontal area. Doublure extending adaxially, with terrace lines only on marginal curve, absent on ventral dorsally sloping part. Thorax with each articulating half ring having distinct transverse ridge near its midlength, anterior wall of articulating furrow rising very steeply to this ridge. Ornament of coarse tubercles on pleural strips not arranged in a single row. Pleural extremity squared, with rounded anterior corner and right angled to slightly pointed posterior corner. Pygidium with pleural areas moderately vaulted, anteriorly almost as high as axis that is sunken between pleural areas, axis well above pleural areas posteriorly. Axis lightly tapering to a well rounded posterior, almost flat transversely between apodemal pits, with apodemal pits becoming more adaxially placed

posteriorly. Facets narrow and short. Ornament of coarse close packed tubercles on prominences and border.

MORPHOGENY

An individual with cranidium 6.5 mm long (Plate 35, fig. 6, lower) has 14 segments and can be interpreted as an holaspide. Another with cranidium 3.5 mm long (Plate 35, fig. 6, upper) has 11 segments of an incomplete thorax and may also be an holaspide. However, some morphological differences between these individuals and the mature ones (11 mm cranidia) are worth noting.

At 3.5 mm ornament is fine with a few larger tubercles, the axial furrow is better impressed (possibly from compaction), anteriorly rounded glabella, $\beta - \delta$ converges more strongly forward, and fixed cheeks are narrower.

At 6.5 mm the ornament is of moderately coarse close spaced tubercles, axial furrow is well impressed, fixed cheeks are narrower, and more convex, caecal ornament is subdued, $\beta - \delta$ converges forward, and thoracic pleura have a line of up to seven large tubercles.

***Asthenopsis butorosa** sp. nov.**
(Fig. 2C; Plate 36, figs. 1-9)

MATERIAL EXAMINED

HOLOTYPE: ANU30649, a cranidium from ANU10325, 5.6 km west of Chummy Bore on the Thornton to Camooweal Road; Currant Bush Limestone, *Ptychagnostus punctuosus* Zone.

OTHER MATERIAL: One complete, 1 T, and 3 P including ANU30645-8 (Pl. 36) from ANU10325; 6C, 3 FC, and 2 P including CPC 17093-6 (Pl. 36) from M161 at the base of the V Creek Limestone 12.8 km east of Morstone Homestead (marked on Camooweal 1:250,000 Geological Map), *Ptychagnostus punctuosus* Zone.

DIAGNOSIS

Asthenopsid with highly vaulted cephalon, rounded anterolateral glabellar corners, poorly impressed anterior axial furrow represented by considerable change in slope, markedly laterally tapering anterior border, anterior branch of facial suture convex diverging forward, with very steeply sloping frontal area more than twice as long at facial suture as sagittally, with relatively close packed ornament of coarse tubercles on border,

* *Bu* (Lat.) large, *torus* (Lat.) rounded protuberance, refers to the coarse tubercular ornament.

frontal area, fixed cheeks, glabella, occipital ring, thoracic and pygidial axes and pleura.

DESCRIPTION

Cranidium (up to 16 mm long) with highly vaulted cheeks and glabella, with steeply sloping frontal area (especially anterolaterally) and posterior limb, and with glabella standing well above convex cheeks in anterior profile. Glabella tapering slightly forward to 0.75 basal width, with straight to very slightly waisted (at furrow 1p) lateral margins, with anterior axial furrow represented by a considerable change of slope (up to 40°) and hence more distinct than in any other species of the genus. Occipital furrow poorly impressed over axial half, apodemal area dumb-bell shaped extending up onto the rear of lobe 1p and occipital ring.

Glabellar furrows smooth, 1p not expanded at adaxial end and without abaxial dome shaped elevation. Anteromedial muscle scar almost in anterior axial furrow. Anterior border most convex of any in genus, tapering strongly laterally. Border furrow well impressed with prominent axial and lateral anterior convexities. Frontal area moderately convex, almost vertically downsloping at facial suture, with depressions extending forward from axial to border furrows. Fixed cheek width almost equal to basal glabellar width, moderately convex. Facial suture with $\beta - \delta$ abaxially convex and diverging forward. Ornament on glabella (except furrows), frontal area, fixed cheeks (except palpebral lobe and furrow), posterior limb, and posterior border of coarse (up to 0.3 mm diameter) high tubercles, on anterior border and palpebral furrow of slightly finer tubercles, with tubercles on fixed cheeks becoming more widely separated towards the axial furrow.

Free cheek moderately vaulted, with quite high eye socle. Genal spine with convex dorsal surface, and slight adaxial curve in distal portion. Ornament on genal field of close spaced tubercles superimposed on caecal ornament.

Thorax of at least 14 segments (no complete mature thorax known). Axial lobe with coarse tuberculate ornament. Pleural furrow unforked adaxially. Pleural strips with single row of tubercles becoming less distinct on free pleurae. Free pleura with squared to slightly pointed posterolateral corner, with finer tuberculate ornament than elsewhere. Pygidium just over twice as wide as long. Pleural area with three or four pleural furrows and one interpleural furrow. Facets short, narrow, and directed strongly

posteriorly. Fulcrum prominently raised. Marked posterior excavation on first axial ring.

MORPHOGENY

Cranidium 3.5 mm long (Plate 36, fig. 1) much less vaulted, with coarse but sparse ornament, anterior part of facial suture converging forward.

Cranidium 5.5 mm long (Plate 36, fig. 3) vaulted, with coarse, closer spaced ornament, anterior part of facial suture convex and diverging laterally, fixed cheeks higher than glabella.

*Asthenopsis opalensis** sp. nov.

(Fig. 2B; Plate 37, figs. 1-4;
Plate 38, figs. 1, 2)

MATERIAL EXAMINED

HOLOTYPE: CPC17098, a cranidium from MNF15, 1.6 km south of the junction of Opal Creek and the O'Shanassy River; Mailchange Limestone, *Ptychagnostus punctuosus* Zone.

OTHER MATERIAL: Six C, 1 FC, and 1 P including CPC17097, and 17099-102 (Pls. 37 and 38) from MNF15.

DIAGNOSIS

Asthenopsid with anterolaterally rounded glabella standing well above fixed cheeks, moderate cephalic convexity, four pairs of lateral glabellar furrows with smooth or punctate surfaces, distinctive occipital apodemal pits, anteriorly placed occipital node, eye ridges of three parallel trunks, straight strongly convergent anterior branches of facial suture, very fine close packed papillose ornament overlain by sparse larger tubercles. Pygidium transverse, weakly vaulted, with papillose ornament.

DESCRIPTION

Cranidium moderately convex, with glabella standing above convex fixed cheeks, a moderately steep frontal area, and a moderately arched anterior border. Glabella with rounded anterolateral corners, convex anterior, with straight only slightly tapering lateral margins, with four pairs of lateral glabellar furrows and an anteromedial muscle scar. Occipital furrow shallow over axial half. Occipital apodemal pit distinctive, with wavy slightly raised smooth areas both anteriorly and posteriorly giving an hour glass shape with long axis transverse. Furrow 3p slightly arcuate, directed very slightly to the

*Named for Opal Creek on which it is found.

posterior adaxially and not connected to axial furrow. Furrow 4p short narrow, directed slightly anteriorly out of fossula very close to glabellar anterior. Glabellar furrows either smooth or finely punctate. Axial furrow crossed by low distinct diverticula at occipital ring and lobe 1p, 2p and 3p. Fossulae not at all distinct. Frontal area flat short and downsloping axially but convex laterally, with both slope and length (to twice sagittal length) increasing laterally. Eye ridges consisting of three parallel trunks (not visible in all specimens) with the median one highest and joining the anterior one just abaxial to the fossula. Parafrontal band low, arising out of fossula, not visible on all specimens. Palpebral lobe flat only slightly upturned laterally, anterior opposite anterior of lobe 2p, posterior level with anterior of lobe 1p. Palpebral furrow straight to slightly abaxially convex, deepening posteriorly. Fixed cheeks 0.9 of basal glabellar width, slightly convex and horizontal, with sparse tubercles over an extremely faint anastomosing caecal network radiating from the axial furrow posteriorly. Facial suture with $\delta - \beta$ straight, converging strongly anteriorly, $\epsilon - \omega$ concave adaxially then straight. Posterior border much longer and flatter beyond fulcrum. Free cheek moderately vaulted, with β in border furrow. Border flat throughout. Genal field with sparse, coarse tubercles superimposed on faint caecal network.

Pygidium transverse, with well rounded margin, and flat pleural areas. Two pleural furrows and an interpleural furrow present. Anterior pleural strip of first segment lengthening well inside fulcrum, weakly convex throughout. Marked posterior excavation in first axial ring.

Asthenopsis sp. nov.
(Plate 32, fig. 6)

MATERIAL EXAMINED

One complete, but damaged, exoskeleton (CPC17069) from 12 km south of Douglas Spring on the Morstone to Undilla Road. It occurs in the V Creek Limestone in the *Ptychagnostus nathorsti* Zone in association with *Asthenopsis levior* and *Papyriaspis lanceola*.

DESCRIPTION

This specimen, being somewhat damaged anteriorly and distorted by several cracks, cannot be satisfactorily compared with other species on cranial features. Only those features that are at variance with the description of *A. levior* above, are referred to here.

It has a flatter border on the free cheek. The genal spine is not deflected. The pygidium has only a weakly convex pleural area and a poorly defined border. The thorax has 16 segments, and a tuberculate pleural ornament. The segments are individually shorter than their corresponding number in *A. levior* whether matching them (i.e. 14 against 14) from the anterior or posterior.

REMARKS

Although this specimen could be included in *A. levior* as representing a population well away from the topotype population I believe that the undeflected genal spine alone, is sufficient to separate it at the species level. In the absence of other material I am reluctant to erect a new name but am confident further collecting will necessitate the assignment of one.

Distinguishing features of the five new northern Australian species described herein are outlined in Table 1.

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TABLE 1: DISTINGUISHING FEATURES OF SPECIES OF ASTHENOPSIS

Characters	<i>A. levior</i>	<i>A. queenslandica</i>	<i>A. rhinostrongyla</i>	<i>A. unguinsepta</i>	<i>A. butorosa</i>	<i>A. opalensis</i>
Bl/BGw	0.31	0.38	0.36	0.38	0.28	0.24
Cw/BGw	0.82	0.73	0.80	0.83	0.92	0.90
Mature cheek ornament	Nil or finely papillose	Fine with few larger tubercles	Tuberculate, sparse	Tuberculate, dense	Coarse tuberculate, dense	Fine with few larger tubercles
Anterior border profile	Horizontal	Slightly arched	Horizontal	Slightly arched	Markedly convex	Moderately convex
General cephalic convexity	Moderate	Little	Moderate	Little	Considerable	Moderate
Occipital node	Medial	Anterior	Anterior	Medial	?	Anterior
Anterior course of facial suture	Converging or parallel and convex	Converging straight	Diverging convex	Converging convex	Diverging convex	Converging straight
Eye ridge	Double	Double	Double	Double	Single	Triple
Pleural tips	Spinose	Squared	Rounded	Squared	Squared	?
Pl/Pw	0.46	0.32	0.30	0.42	0.42	0.33
Convexity of pleural areas	Considerable	Nil	Nil	Moderate	Moderate	Nil
Concavity in posterior margin	Yes	No	No	No	No	No

Bl = brim length [sag.]; BGw = basal glabellar width; Cw = fixed cheek width at level of δ ; Pl = pygidial length; Pw = pygidial width

PLATE 31

Asthenopsis levior Whitehouse, 1939

(1, 4, 6, 7, 8 from the type locality on V Creek)

FIG. 1: Thorax and pygidium, UQF3340, (figured by Whitehouse, 1939, pl. 22, fig. 20), $\times 1.2$.

FIG. 2: Latex cast of damaged early holaspisid exoskeleton, CPC17064, $\times 6$, from M41.

FIG. 3: Early holaspisid cranidium, UQF68711, $\times 10$, from UQL3510.

FIG. 4: Pygidium, UQF3339, (figured by Whitehouse, 1939, pl. 22, fig. 19), $\times 2$.

FIG. 5: Damaged cranidium, UQF68712, $\times 4.5$; b, anterior oblique view, from UQL3510.

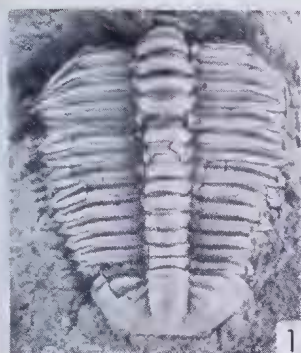
FIG. 6: Damaged cranidium, UQF3338, (figured by Whitehouse, 1939, pl. 22, fig. 18), $\times 2$.

FIG. 7: Latex cast of slightly damaged Holotype exoskeleton, UQF3337, (figured by Whitehouse, 1939, pl. 22, fig. 17), $\times 2.5$; a, lateral oblique view, b, dorsal view.

FIG. 8: Large slightly damaged complete exoskeleton, UQF44314, $\times 1.5$.

FIG. 9: Ventral view of left free cheek, CPC17065, $\times 3$ from M139.

Illustrations are dorsal views unless otherwise stated.



1



2



3



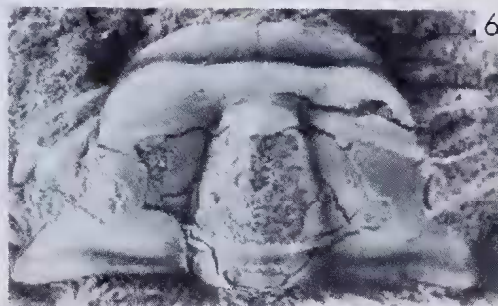
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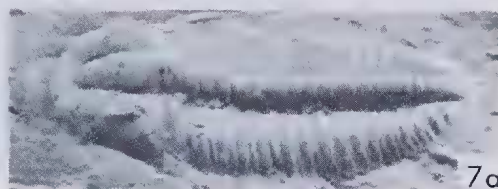
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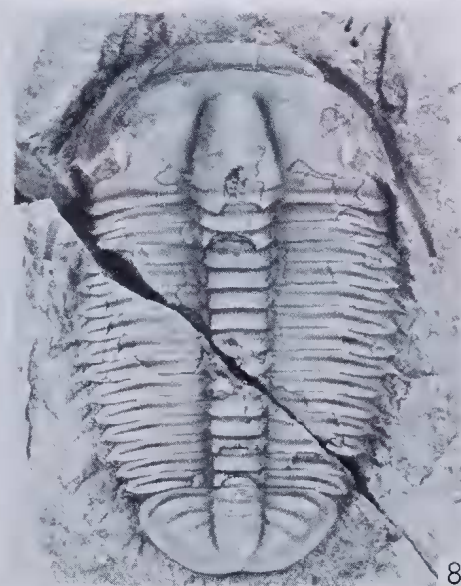
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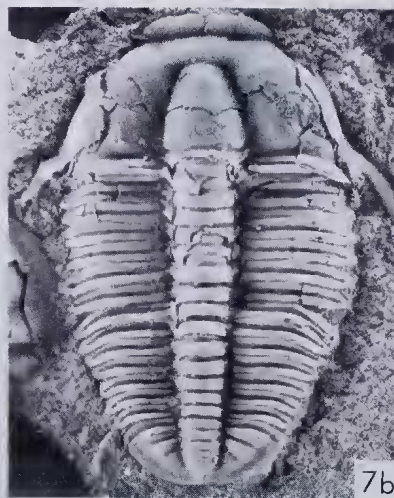
6



7a



8



7b



9

PLATE 32

Asthenopsis levior Whitehouse, 1939

FIG. 1: Damaged cranidium, CPC17066, $\times 2.5$, from M247.

FIG. 2: Cranidium, UQF68713, $\times 1.5$, from UQL469.

FIG. 3: Damaged pygidium exhibiting well developed caeca passing into the border, UQF68714, a, $\times 2.5$, b, $\times 7$, from UQL469.

FIG. 4: Cranidium, CPC17067, $\times 3$, from Douglas Creek halfway from the Old Burketown Road to the O'Shanassy River.

FIG. 5: Cranidium, CPC17068, $\times 3$, same locality as FIG. 4.

Asthenopsis sp. nov.

FIG. 6: Damaged exoskeleton, CPC17069, $\times 2.2$, from 12 km south of Douglas Creek on the Morstone to Undilla Road.

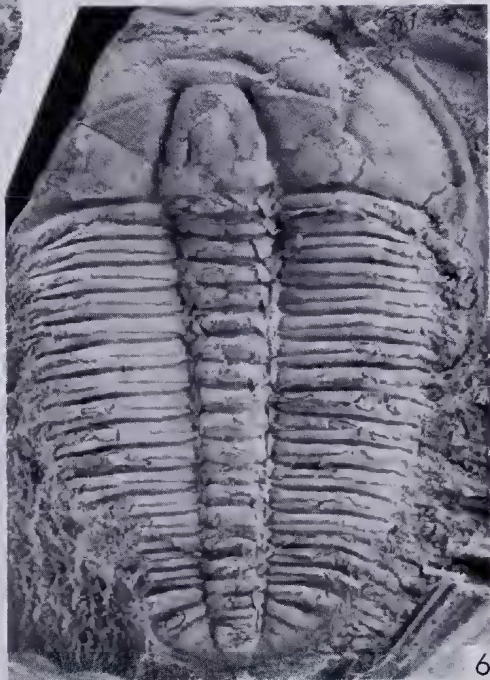
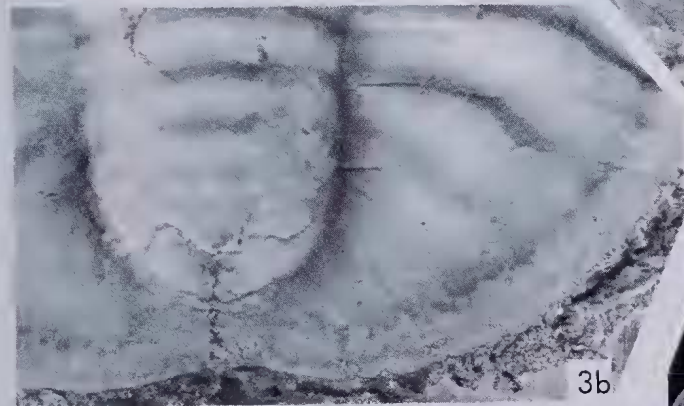


PLATE 33

Asthenopsis queenslandica sp. nov.
(All material is from M243)

FIG. 1: Cranidium, CPC17070, a, $\times 4$, b, $\times 6.5$.

FIG. 2: Small cranidium, CPC17071, $\times 9$.

FIG. 3: Right free cheek, CPC17072, $\times 3$.

FIG. 4: Small cranidium, CPC17073, $\times 7$.

FIG. 5: Holotype exoskeleton, CPC17074, $\times 3$.

FIG. 6: Large damaged exoskeleton without free cheeks, CPC17075,
 $\times 2.5$.

FIG. 7: Large damaged exoskeleton without free cheeks, CPC17076,
 $\times 5$.

FIG. 8: Pygidium, CPC17077, $\times 6.5$.

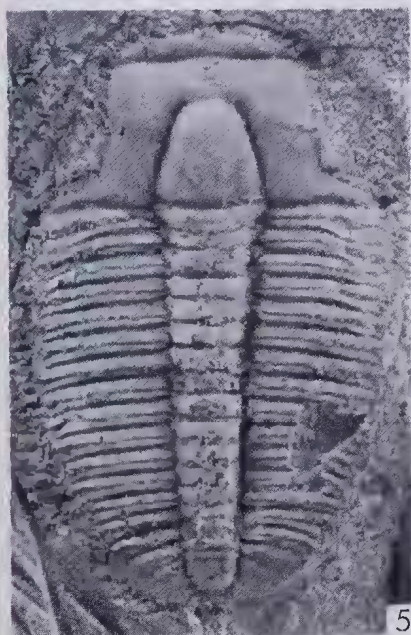
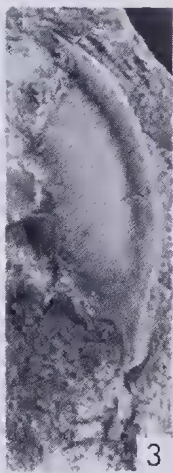
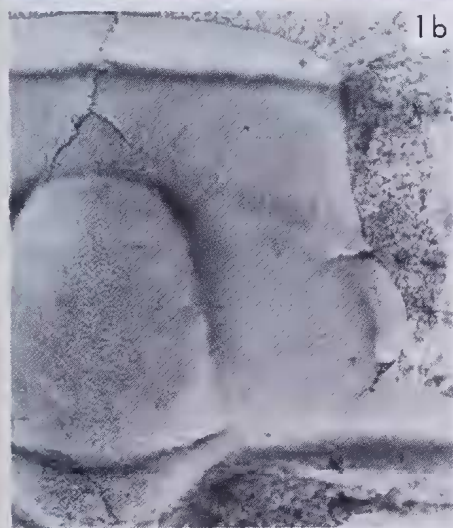
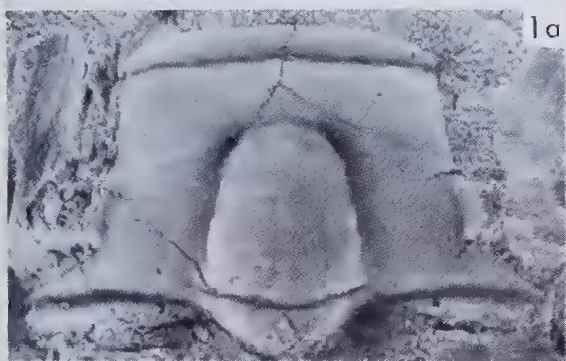


PLATE 34

Asthenopsis queenslandica sp. nov.

FIG. 1: Cranium, CPC17078, $\times 4.5$, a, anterior view, from M243.

Asthenopsis rhinostrongyla sp. nov.

(All material is from H138)

FIG. 2: Small cranium, CPC17079, $\times 5.5$.

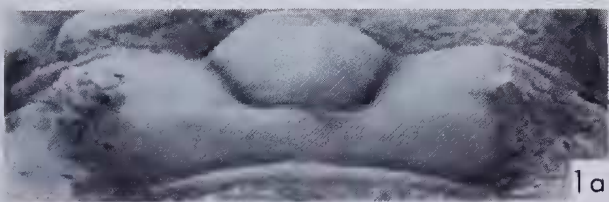
FIG. 3: Holotype cranium, CPC17080, $\times 3.5$, a, anterior view.

FIG. 4: Ventral view of right free cheek, CPC19081, $\times 4.5$.

FIG. 5: Thoracic fragment, CPC17082, $\times 2.5$, b, lateral view.

FIG. 6: Latex cast of cranium, CPC17083, a, $\times 4.2$, b, lateral oblique view, $\times 4$.

FIG. 7: Left free cheek, CPC17084, $\times 4$.



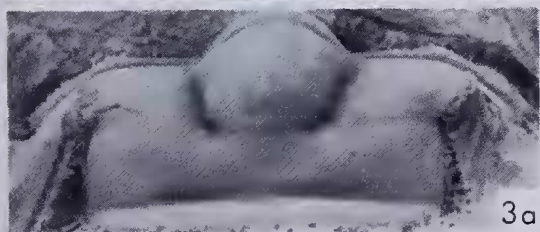
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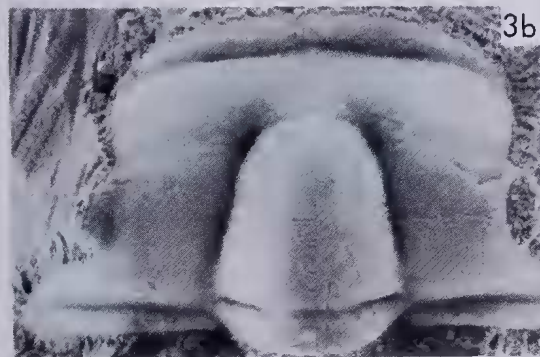
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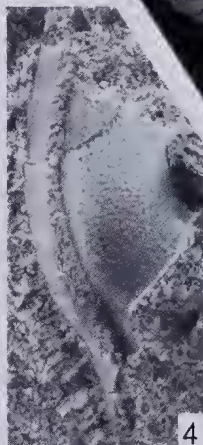
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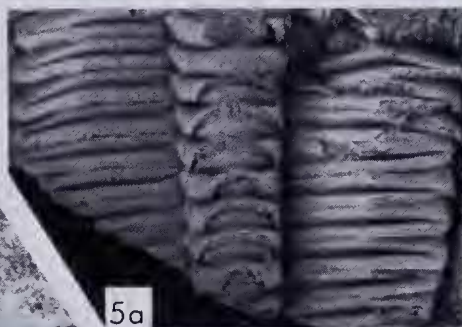
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3b



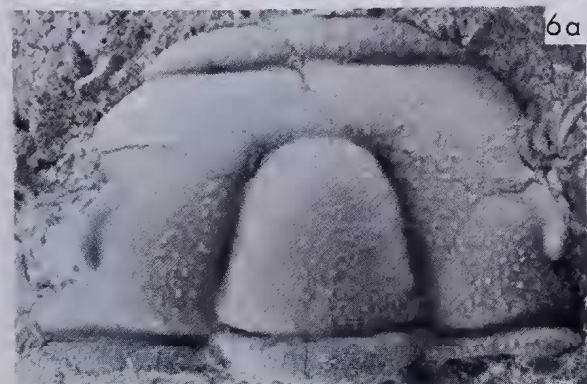
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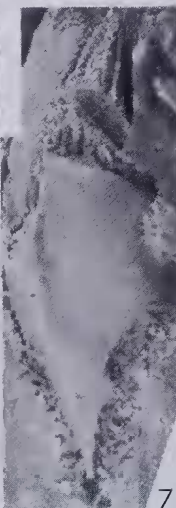
5a



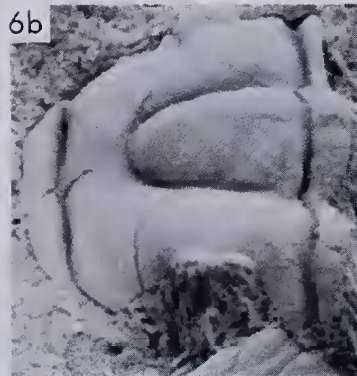
5b



6a



7



6b

PLATE 35

Asthenopsis rhinostrongyla sp. nov.

FIG. 1: Left free cheek, CPC17085, $\times 5$, b, lateral view, from H138.

FIG. 2: Pygidium, CPC17086, $\times 6$, from H138.

Asthenopsis unquinsepta sp. nov.

(All material is from M157)

FIG. 3: Pygidium, CPC17087, $\times 3$.

FIG. 4: Left free cheek, CPC17088, $\times 4$.

FIG. 5: Holotype cranidium, CPC17089, $\times 3$, a, lateral view.

FIG. 6: Two small individuals slightly damaged, CPC17090, $\times 3$.

FIG. 7: Latex cast of left free cheek, CPC17091, $\times 4$.

FIG. 8: Cranidium and thorax, CPC17092, $\times 2.5$.

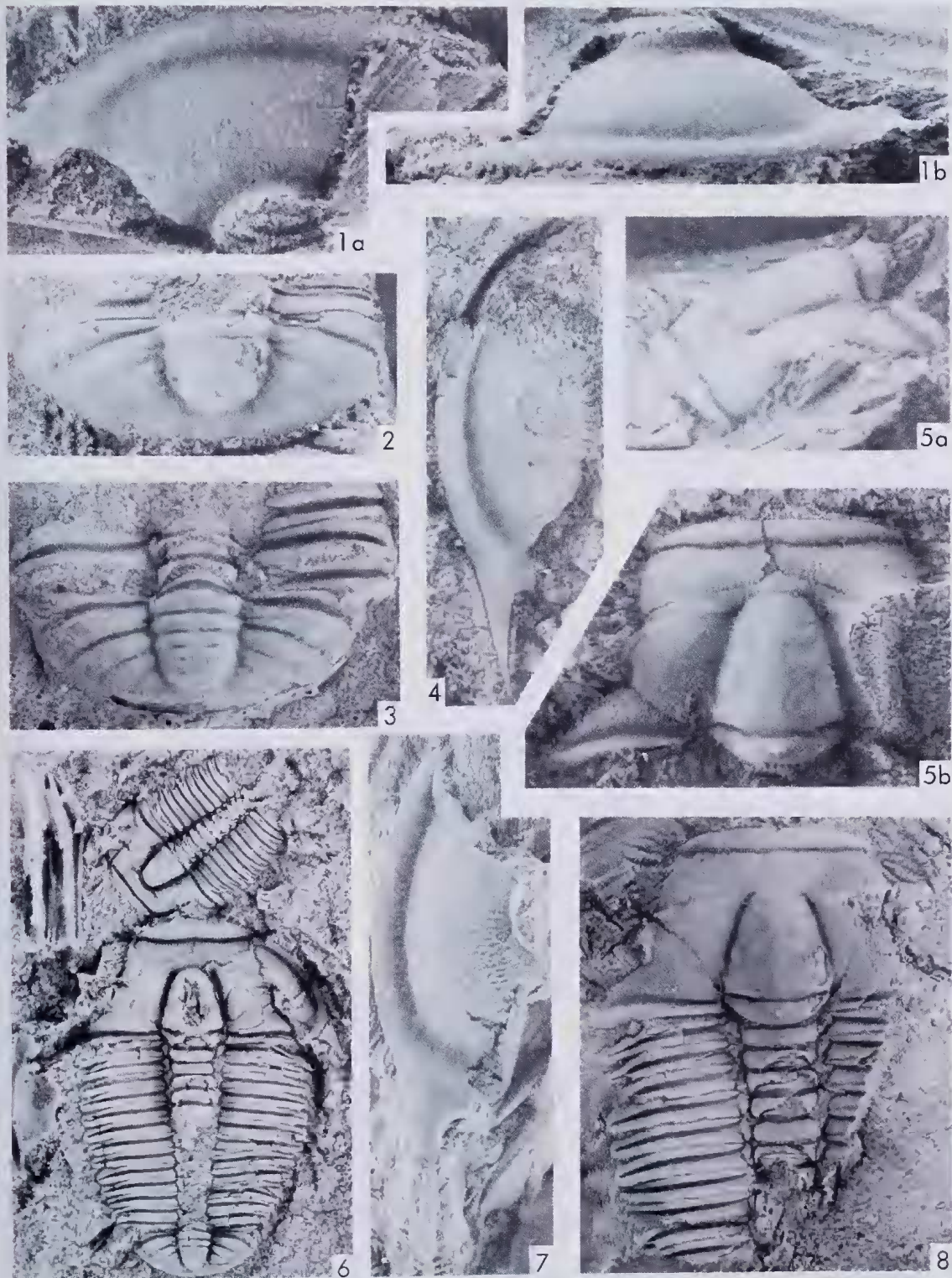


PLATE 36

Asthenopsis butorosa sp. nov.

FIG. 1: Latex cast of complete (less free cheeks) early holaspide, ANU30645, $\times 5$, from ANU10325.

FIG. 2: Pygidium, CPC17093, $\times 3.5$, from M161.

FIG. 3: Small cranidium, CPC17094, $\times 7$, b, lateral oblique view, from M161.

FIG. 4: Latex cast of pygidium and damaged thorax, ANU30646, $\times 3$, from ANU10325.

FIG. 5: Cranidium, CPC17095, a, lateral oblique view, $\times 4$, b, dorsal view, $\times 4$, c, anterior oblique view, $\times 5$, from M161.

FIG. 6: Right free cheek, ANU30647, $\times 5$, from ANU10325.

FIG. 7: Latex cast of pygidium, ANU30648, $\times 5$, from ANU10325.

FIG. 8: Holotype cranidium, ANU30649, $\times 2.8$, from ANU10325.

FIG. 9: Cranidium, CPC17096, $\times 3$, from M161.

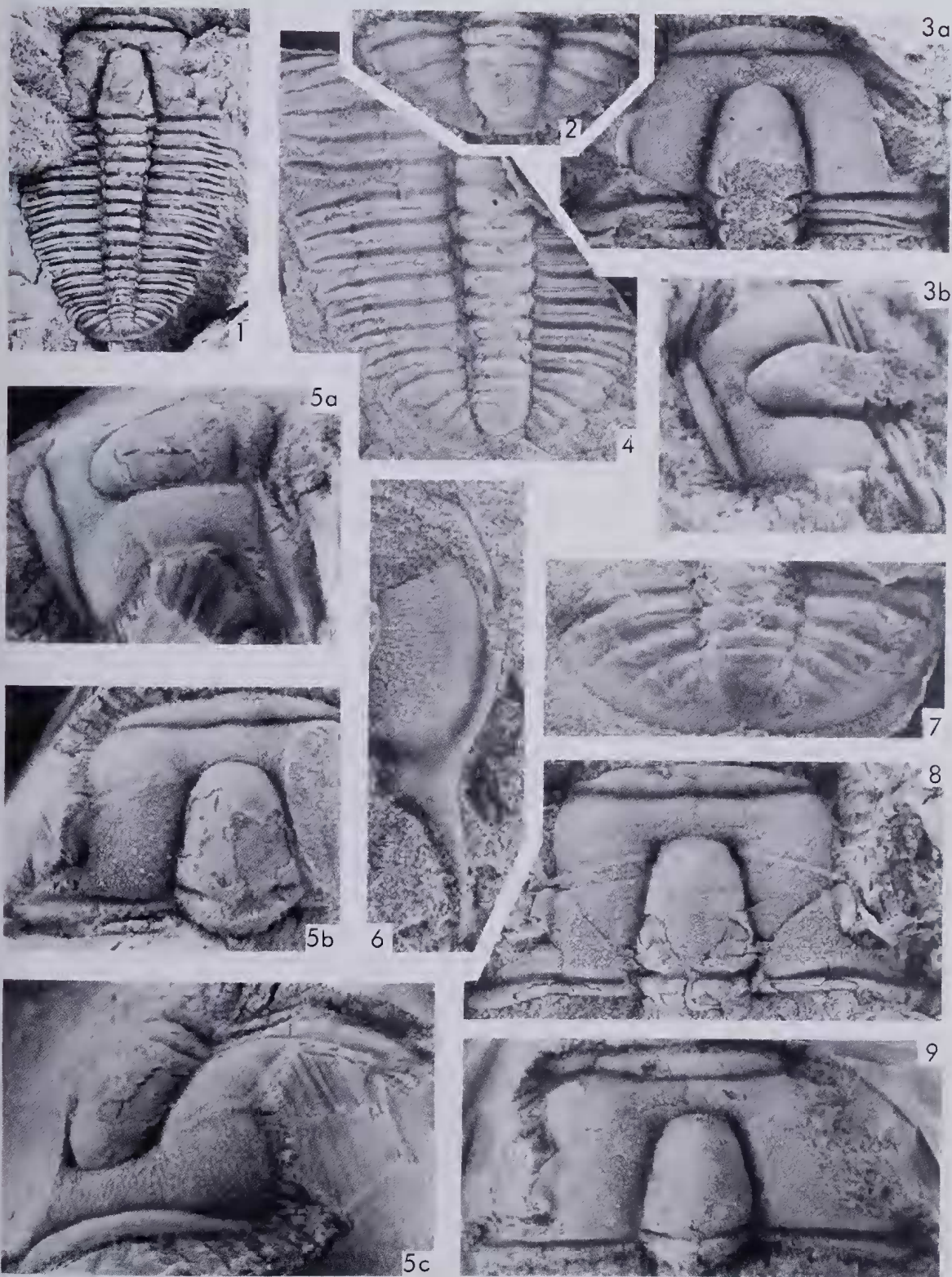


PLATE 37

Asthenopsis opalensis sp. nov.

(All material is from MNF15)

FIG. 1: Cranidium, CPC17097, $\times 3$.

FIG. 2: Holotype cranidium, CPC17098, a, anterior view, $\times 3$, b, $\times 4$.

FIG. 3: Cranidium, CPC17099, $\times 4$, a, anterior oblique view.

FIG. 4: Cranidium, CPC17100, a, $\times 5.5$, b, $\times 6$, c, $\times 2.5$.

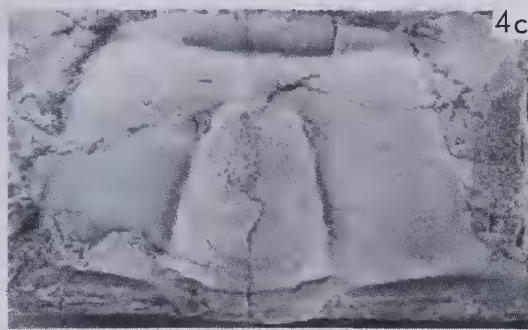
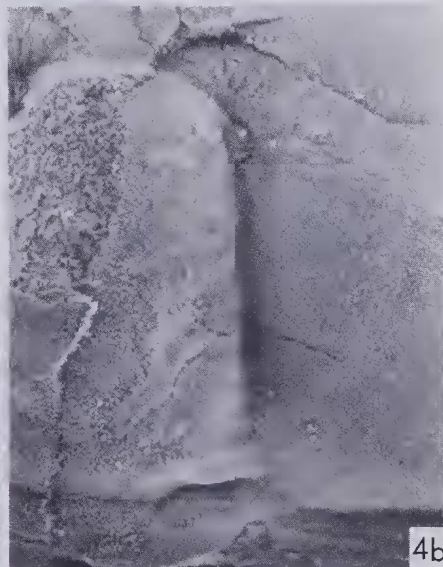


PLATE 38

Asthenopsis opalensis sp. nov.

FIG. 1: Cranidium, CPC17101, $\times 3$, from MNF15.

FIG. 2: Pygidium, CPC17102, $\times 4.5$, from MNF15.

Asthenopsis sp. cf. *A. rhinostrongyla* sp. nov.

FIG. 3: Cranidium (mostly exfoliated), CPC17103, $\times 3$, a, lateral view,
b, from M156.

FIG. 4: Right free cheek, CPC17104, $\times 4.5$, from M156.

FIG. 5: Pygidium, UQF68715, $\times 5$, from UQL447.

FIG. 6: Cranidium, CPC17105, $\times 3$, a, anterior view.

FIG. 7: Cranidium, UQF68716, $\times 4.5$, b, anterior oblique view.

